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Comprehensive Report to Congress Clean Coal Technology Program

SOX-NOX-ROX Box Flue Gas Clean-Up Demonstration Project

A Project Proposed By Babcock & Wilcox

November 1989

U.S. Department of Energy
Office of Fossil Energy
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1.0 EXECUTIVE SUMMARY

In December 1987, Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million to conduct cost-shared Innovative Clean Coal Technology (ICCT) projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) issued by the Department of Energy (DOE) in February 1988 solicited proposals to demonstrate technologies capable of being commercialized in the 1990's, more cost effective than current technologies, and capable of achieving significant reduction of sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) emissions from existing coal-burning facilities, particularly those that contribute to transboundary and interstate pollution.

In response to the PON, fifty-five proposals were received by the DOE in May 1988. After evaluation, sixteen projects were selected for award. These projects involve both advanced pollution control technologies that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating-plant capacity and extend the operating life of the facility.

One of the sixteen projects selected for funding is a project proposed by Babcock & Wilcox (B&W) to demonstrate the SOX-NOX-ROX BOX (SNRB) flue gas clean-up process. The SNRB process combines the removal of SO_2, NO_x, and particulates within one unit - a high temperature baghouse.

Sulfur dioxide is removed by injecting a sorbent, either sodium- or calcium-based, into the flue gas between the upper part of the boiler combustion zone and the economizer outlet. The sorbent reacts with the SO_2 to form a solid particulate, which is removed in the baghouse. Preliminary evaluations, based on reagent costs and solid waste disposal costs, indicate that calcium-based sorbents would be preferred reagents for applications in Eastern regions of the United States, while sodium-based sorbents would be preferred for Western applications. Flyash is also removed by the baghouse.

The NO_x reduction is accomplished by selective catalytic reduction (SCR) using ammonia injected upstream of the baghouse. Some NO_x removal occurs in the presence of injected sorbent, while the balance is removed in the presence of the SCR catalyst in the baghouse. The catalyst converts ammonia and NO_x to nitrogen and water vapor in the temperature range at which the baghouse operates -- 600 to 800 degrees fahrenheit (°F).

The SNRB process is expected to remove 70% to 90% of the SO_2, up to 90% of the NO_x emissions, and 99+% of the particulate emissions from coal-fired boilers. If successfully demonstrated, this project would establish an alternative process technology to conventional wet and dry Flue Gas Desulfurization (FGD) processes with less physical space requirements and lower capital and operating costs while enabling higher overall plant efficiency.

The project will be conducted at the 156-megawatt (MW) coal-fired R.E. Burger Plant Unit No. 5 (Boiler No. 8) owned by Ohio Edison Company. This plant is located in Dilles Bottom, Ohio, as shown in Figure 1, and is presently in commercial operation. Ohio bituminous coal (approximately 2.9% sulfur) will be used in this project. A 5-MW equivalent flue gas slipstream will be treated by the SNRB demonstration plant. This size was selected because it is large enough to provide results representative of the technology at a commercial-scale utility SNRB installation at a reasonable cost. A facility of this size will also require only minimal plant downtime to install.

The demonstration project will be performed over a forty-four month period, and the project activities include design, permitting, and installation of equipment; testing; data collection and analysis; site restoration; and reporting of results.

The total estimated project cost is $10,640,293. The cofunders are B&W ($536,559); DOE ($4,875,246); the Ohio Coal Development Office (OCDO) ($4,374,998); the Electric Power Research Institute (EPRI) of Palo Alto, California ($500,000); Ohio Edison Company ($78,200); the Norton Company of Akron, Ohio ($174,290); and the Minnesota Mining and Manufacturing Company (3M) of St. Paul, Minnesota ($101,000). Testing is scheduled to begin in late 1991. Overall project completion is scheduled to occur in early 1993.

2.0 INTRODUCTION AND BACKGROUND

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and utilization processes to provide efficient and economic energy options. These technology developments permit the use of coal in a cost-effective and environmentally acceptable manner.

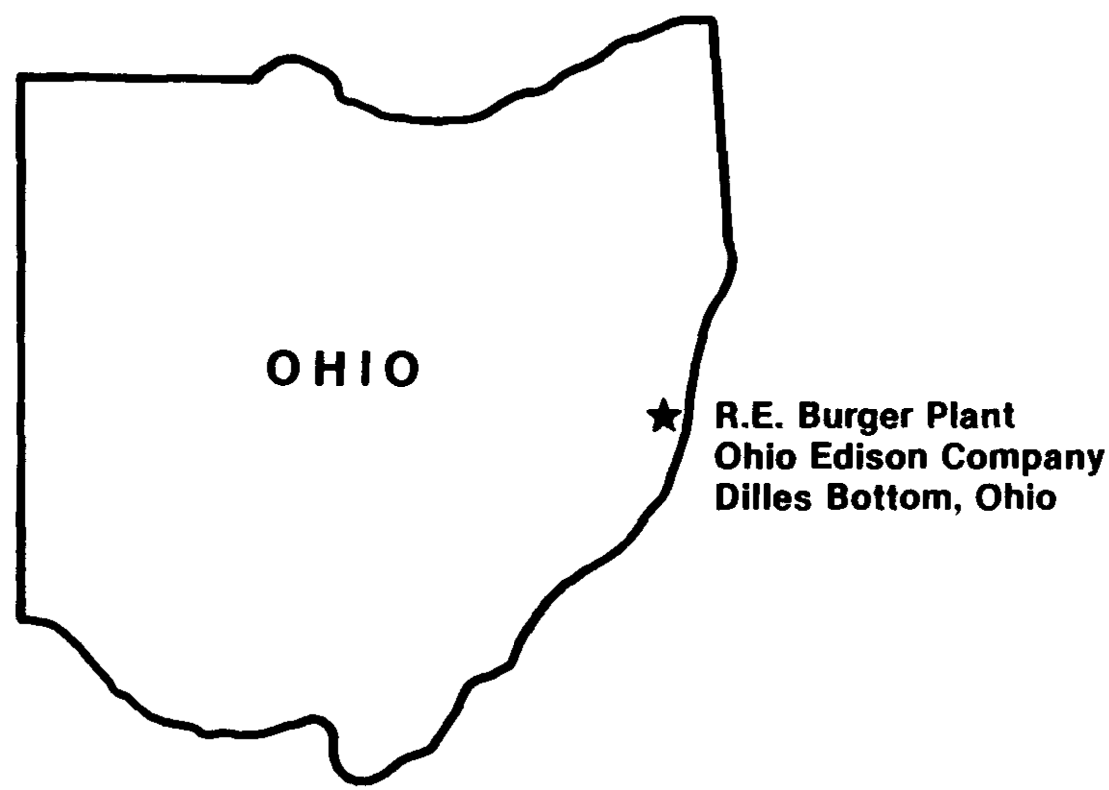

FIGURE 1. B&W SNRB DEMONSTRATION PROJECT SITE LOCATION.

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2.1 Requirement for Report to Congress

In December 1987, Congress made funds available for the ICCT Program in Public Law No. 100-202, "An Act Making Appropriations for the Department of Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes" (the "Act"). This Act provided funds for the purpose of conducting cost-shared clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities and authorized DOE to conduct the ICCT Program. Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million, which will remain available until expended, and of which (1) $50,000,000 was available for the fiscal year beginning October 1, 1987; (2) an additional $190,000,000 was available for the fiscal year beginning October 1, 1988; (3) an additional $135,000,000 will be available for the fiscal year beginning October 1, 1989; and (4) $200,000,000 will be available for the fiscal year beginning October 1, 1990. Of this amount, $6,782,000 million will be set aside for the Small Business and Innovative Research Program, and is unavailable to the ICCT Program.

In addition, after the projects to be funded had been selected, DOE prepared a comprehensive report on the proposals received. The report was submitted in October 1988 and was entitled "Comprehensive Report to Congress: Proposals Received in Response to the Innovative Clean Coal Technology Program Opportunity Notice" (DOE/FE-0114). Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for ICCT projects, summarizes the project proposals that were received, provides information on the technologies that are the focus of the ICCT Program, and reviews specific issues and topics related to the solicitation.

Public Law No. 100-202 directed DOE to prepare a full and comprehensive report to Congress on each project selected for award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the SNRB Flue Gas Cleanup Demonstration Project.

2.2 Evaluation and Selection Process

A PON was issued by DOE on February 22, 1988, to solicit proposals for conducting cost-shared ICCT demonstrations. Fifty-five proposals were received. All proposals were required to meet the six qualification criteria provided in the PON. Failure to satisfy one or more of these criteria resulted in rejection of the proposal. Proposals that passed Qualification Review proceeded to

Preliminary Evaluation. Three preliminary evaluation requirements were identified in the PON. Proposals were evaluated to determine whether they met these requirements; those proposals that did not were rejected.

Of those proposals remaining in the competition, each offeror's Technical Proposal, Business and Management Proposal, and Cost Proposal were evaluated. The PON provided that the Technical Proposal was of somewhat greater importance than the Business and Management Proposal and that the Cost Proposal was of minimal importance; however, everything else being equal, the Cost Proposal was very important.

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors," addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with factors involved in the commercialization process. The criteria in this section provided for consideration of (1) the potential of the technology to reduce total national emissions of SO_2 and/or NO_x emissions and to reduce transboundary and interstate air pollution with minimal adverse environmental, health, safety, and socioeconomic (EHSS) impacts; and (2) the potential of the proposed technology to improve the cost-effectiveness of controlling emissions of SO_2 and NO_x when compared to commercially available technology options.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "predemonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Criteria in this category provided for the consideration of the following: the technical readiness for scale-up; the adequacy and appropriateness of the demonstration project; the EHSS and other site-related aspects; the reasonableness and adequacy of the technical approach; and the quality and completeness of the Statement of Work.

The Business and Management Proposal was evaluated to determine the business and management performance potential of the offeror, and was used as an aid in determining the offeror's understanding of the technical requirements of the PON. The Cost Proposal was reviewed and evaluated to assess the validity of the proposer's approach to completing the project in accordance with the proposed Statement of Work and the requirements of the PON.

Consideration was also given to the following program policy factors:

1. The desirability of selecting projects for retrofitting and/or repowering existing coal-fired facilities that collectively represent a diversity of methods, technical approaches, and applications (including both industrial and utility);

2. The desirability of selecting projects that collectively produce some near-term reduction of transboundary transport of emitted SO_2 and NO_x; and

3. The desirability of selecting projects that collectively represent an economic approach applicable to a combination of existing facilities that significantly contribute to transboundary and interstate transport of SO_2 and NO_x in terms of facility types and sizes, and coal types.

The PON also provided that, in the selection process, DOE would consider giving preference to projects located in states where the rate-making bodies of those states treat innovative clean coal technologies the same as pollution control projects or technologies. The inclusion of this project selection consideration was intended to encourage states to utilize their authorities to promote the adoption of innovative clean coal technology projects as a means of improving the management of air quality within their areas and across broader geographical areas.

The PON provided that this consideration would be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

An overall strategy for compliance with the National Environmental Policy Act (NEPA) was developed for the ICCT Program, consistent with the Council on Environmental Quality NEPA regulations and the DOE guidelines for compliance with NEPA. This strategy includes both programmatic and project-specific environmental impact considerations during and after the selection process.

In light of the tight schedule imposed by Public Law No. 100-202 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic and project-specific environmental data and analyses as a discrete part of their proposal.

The DOE strategy for NEPA compliance has three major elements. The first involves preparation of a comparative programmatic environmental impact analysis, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental analysis ensures that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives are evaluated in the selection process. The second element involves preparation of a preselection project-specific environmental review. The third element provides for preparation by DOE of publicly available site-specific NEPA documents for each project selected for financial assistance under the PON.

No funds from the ICCT Program will be provided for detailed design, construction, operation, and/or dismantlement until the third element of the NEPA process has been successfully completed. In addition, each Cooperative Agreement entered into will require an Environmental Monitoring Plan (EMP) to ensure that significant technology, project, and site-specific environmental data are collected and disseminated.

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, sixteen proposals were selected for award. The SNRB proposal submitted by B&W was one of these proposals.

3.0 TECHNICAL FEATURES

3.1 Project Description

The B&W SNRB project will demonstrate that the combination of sorbent injection and ammonia injection with SCR and a high temperature baghouse is an efficient and economical means of removing the acid rain precursors (SO_2 and NO_x), as well as particulate emissions from utility boiler flue gas. This project will be the first field demonstration of SNRB technology relevant to industrial and utility boiler operators.

The primary advantage of the SNRB process over conventional pollution control processes is the combined removal of SO_2, NO_x, and particulates in a single unit -- a high-temperature baghouse. This eliminates the need for a separate piece of equipment for the removal of each of the pollutants, thereby reducing site area requirements. Capital and operating costs are projected to be lower, making the process attractive for both new and retrofit applications. In addition, the potential for improved boiler efficiency exists (lower exit gas temperature) because of a very low SO_3 concentration in the flue gas following SNRB processing.

The demonstration will be conducted at Ohio Edison's R.E. Burger Plant Unit No. 5 (Boiler No. 8). This boiler is a pre-NSPS (New Source Performance Standards), 156-MW coal-fired unit which utilizes Ohio bituminous coal (approximately 2.9% sulfur). A 5-MW equivalent slipstream from the boiler will be used for the demonstration. This size demonstration is large enough to use key components and provide test results representative of a utility SNRB, yet small enough to be economical while causing minimal downtime.

The goal of this program is to prove the technical and economic feasibility of the SNRB technology on a commercial scale. If successful, the process will achieve 70% to 90% SO_2 removal, up to 90% NO_x removal, and 99+% particulate removal at lower capital and operating and maintenance (O&M) costs than other systems.

3.1.1 Project Summary

Project Title:	SOX-NOX-ROX BOX Flue Gas Clean-Up Demonstration Project
Proposer:	Babcock and Wilcox (B&W)
Project Location:	Dilles Bottom, Ohio (Ohio Edison's R.E. Burger Station) Belmont County
Technology:	Flue Gas Cleanup by Ammonia Injection with Selective Catalytic Reduction, Calcium or Sodium-Based Reagent Injection, and Fabric Filtration.
Application:	New and Retrofit Industrial and Utility Coal-Fired Boilers
Types of Coal Used:	Bituminous (Approximately 2.9% Sulfur) Coal from Ohio
Product:	Environmental Control Technology
Project Size:	5 MWe (10,250 SCFM)
Project Start Date:	July 1, 1989
Project End Date:	February 29, 1993

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Babcock and Wilcox
CoFunders:	U.S. Department of Energy, Ohio Coal Development Office, Electric Power Research Institute, Norton Company, Minnesota Mining and Manufacturing Company, and Ohio Edison Company.
Estimated Project Cost:	\$10,640,293

Project Cost Distribution:

Participant Share(%)	DOE Share(%)
54.2	45.8

3.2 SNRB Process

3.2.1 Overview of Process Development

The SNRB process, which utilizes ammonia and either a calcium- or sodium-based sorbent injected upstream of a high-temperature baghouse, was patented by B&W and has been under development since 1980. The early work performed by B&W focused on selective catalytic reduction of NO_x in a fabric filter using chromium or cobalt oxides as a NO_x catalyst.

In 1987, B&W conducted pilot-scale tests using ammonia injection with various metal oxide catalysts for NO_x removal and using injection of calcium or sodium compounds for SO_2 removal. A further study was conducted to optimize NO_x and SO_2 reduction with ammonia and sodium bicarbonate injections. Sodium bicarbonate was the most effective SO_2 sorbent tested. Removal rates of greater than 60% and 90% were achieved for NO_x and SO_2, respectively. B&W predicts that, with a Norton Company SCR catalyst and at a higher than conventional SCR operating temperature (practical at a low SO_2-SO_3 concentration), a NOx reduction of 90% can be achieved for the SNRB demonstration unit.

Norton has developed a catalyst for reducing NO_x with ammonia and has been working with B&W since 1981 to develop the SNRB process by providing catalyst and technical assistance. In 1988, pilot-scale development tests, jointly sponsored by B&W and OCDO, were conducted by B&W to demonstrate the feasibility of the Norton Company catalyst in a high-temperature baghouse, to demonstrate the operability of the baghouse for extended periods, and to identify inexpensive reagents for SO_2 removal that can be readily disposed of in a landfill.

Minnesota Mining and Manufacturing Company (3M) has developed a ceramic fiber yarn called Nextel™, which can withstand continuous service temperatures up to 2200°F. This material has been successfully demonstrated at the University of North Dakota Energy and Minerals Research Center (UNDEMRC).

Additional SNRB process development work is being sponsored by B&W and OCDO, including additional calcium-based sorbent testing and system integration studies to determine the optimum location for the baghouse catalyst. The system integration studies will include catalyst and catalyst holder pressure drop tests and bag cleanability tests.

3.2.2 Process Description

The SNRB process, shown schematically in Figure 2, is a three-part process in which sorbent injection is used to control SO_2, SCR is used to control NO_x, and a high temperature baghouse is used to remove particulates.

Sorbent Injection

Sulfur oxides, predominantly SO_2, form during the combustion of sulfur compounds in coal. If the flue gas is untreated, the SO_2 will be discharged to the atmosphere.

One method of removing SO_2 is by sorbent injection, the technique used in this and other similar processes. The sorbent may be sodium-based (sodium bicarbonate, sodium carbonate, nahcolite, or trona) or calcium-based (lime). Preliminary evaluation indicated that calcium-based sorbents will be the preferred reagent for applications in Eastern regions of the United States, while sodium-based sorbents will be preferred in Western Regions. This difference relates to both the relative cost of reagents and the relative cost of waste disposal.

For the calcium-based application of the SNRB process, lime is unloaded from trucks, railroad cars, or barges and conveyed to a storage silo. The sorbent is then mixed with a recycle lime stream and fed to a hydrator. The hydrator, which converts calcium oxide to calcium hydroxide, produces a dry, free-flowing

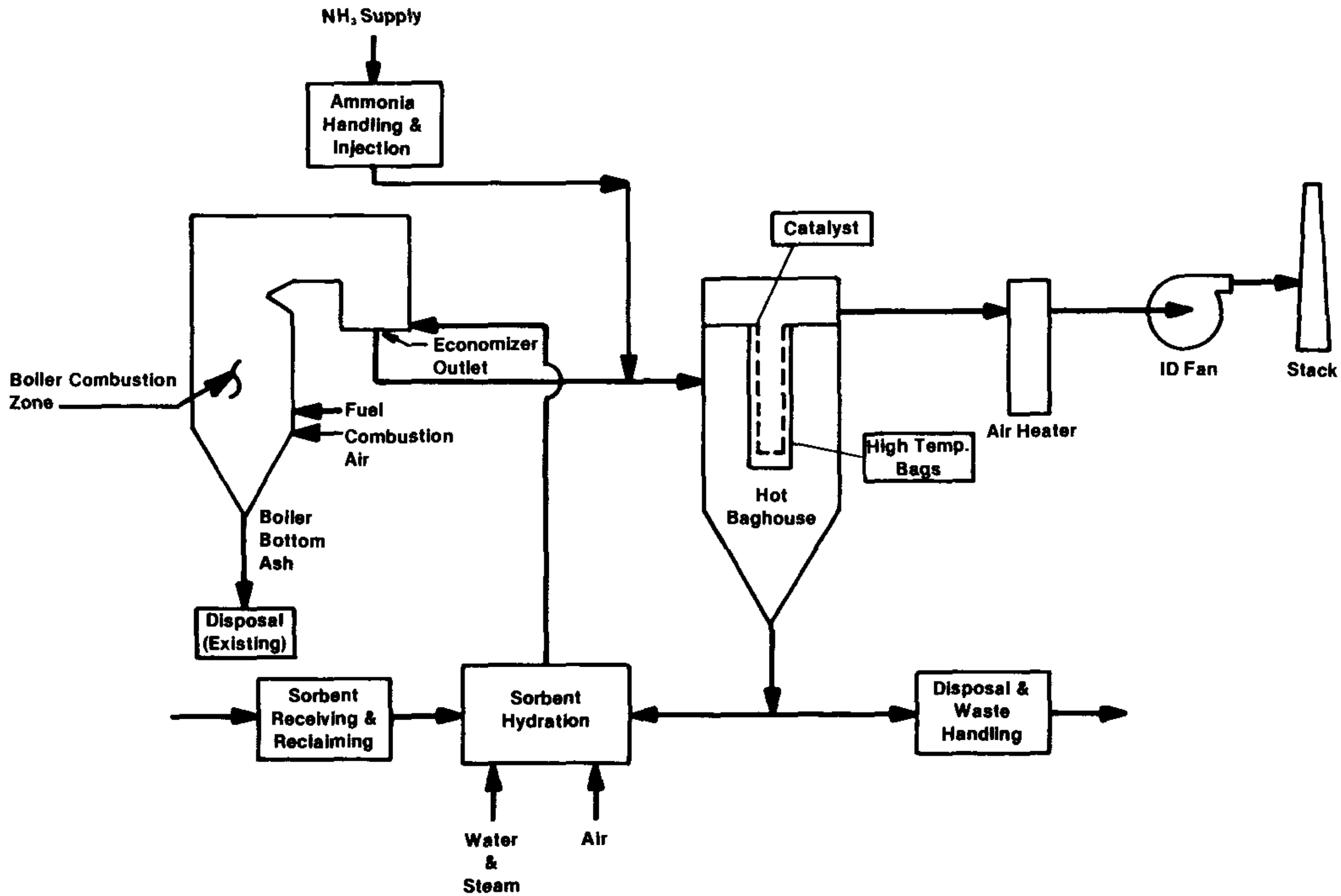

FIGURE 2. SNRB GENERAL SCHEMATIC. (Calcium-Based Application)

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solid, which is pneumatically injected into the flue gas. The sorbent can be injected at any point between the upper part of the boiler combustion zone and the economizer outlet. The sorbent reacts with the SO_2 to form solid calcium sulfate and sulfite particles, which are removed from the flue gas in the baghouse along with fly ash. In the sodium-based system, sorbent is injected into the flue gas without hydration. Also, recycle of unreacted sorbent is unnecessary, as these sorbents are more reactive than calcium-based sorbents.

Selective Catalytic Reduction

Nitrogen oxides, or NO_x, form when nitrogen-containing compounds in the fuel or nitrogen in the combustion air is oxidized. The rate of formation of NO_x depends on flame temperature, the quantity of excess air available for combustion, the nitrogen content of the fuel, and the residence time at high temperature. Greater values for any of these parameters result in a greater tendency to form NO_x.

Reducing the value of any of these parameters will reduce NO_x formation; however, low flame temperature, short residence time, and substoichiometric oxygen result in other pollution problems, such as high emission rates of carbon monoxide, soot, and partially oxidized organic compounds. Also, these NO_x reduction practices result in lower boiler efficiency and a lower than maximum energy utilization of the fuel. Using other means to reduce NO_x formation avoids these undesirable effects.

One process that has been developed is SCR. As shown in Figure 2, ammonia first is injected into the flue gas prior to the baghouse. Some NO_x and ammonia will react in the flue gas upstream of the catalyst, while the majority will be reacted in the presence of the SCR catalyst located in the high-temperature baghouse. The ammonia will catalytically convert NO_x to nitrogen and water vapor.

This subprocess of the overall SNRB process will eliminate up to 90% of the NO_x without producing undesirable pollutants.

High Temperature Baghouse

The key element of the SNRB process is the high-temperature baghouse. Within this single process unit, both fly ash and sorbent solids from SO_2 reduction are removed from the flue gas, and NO_x is catalytically converted into nitrogen and water.

The baghouse will be located between the boiler and the air heater as shown in Figure 2, and will operate in the range of 600°F to 800°F. High-temperature bags will be used. An SCR catalyst will be placed in the baghouse on the clean side of the bags.

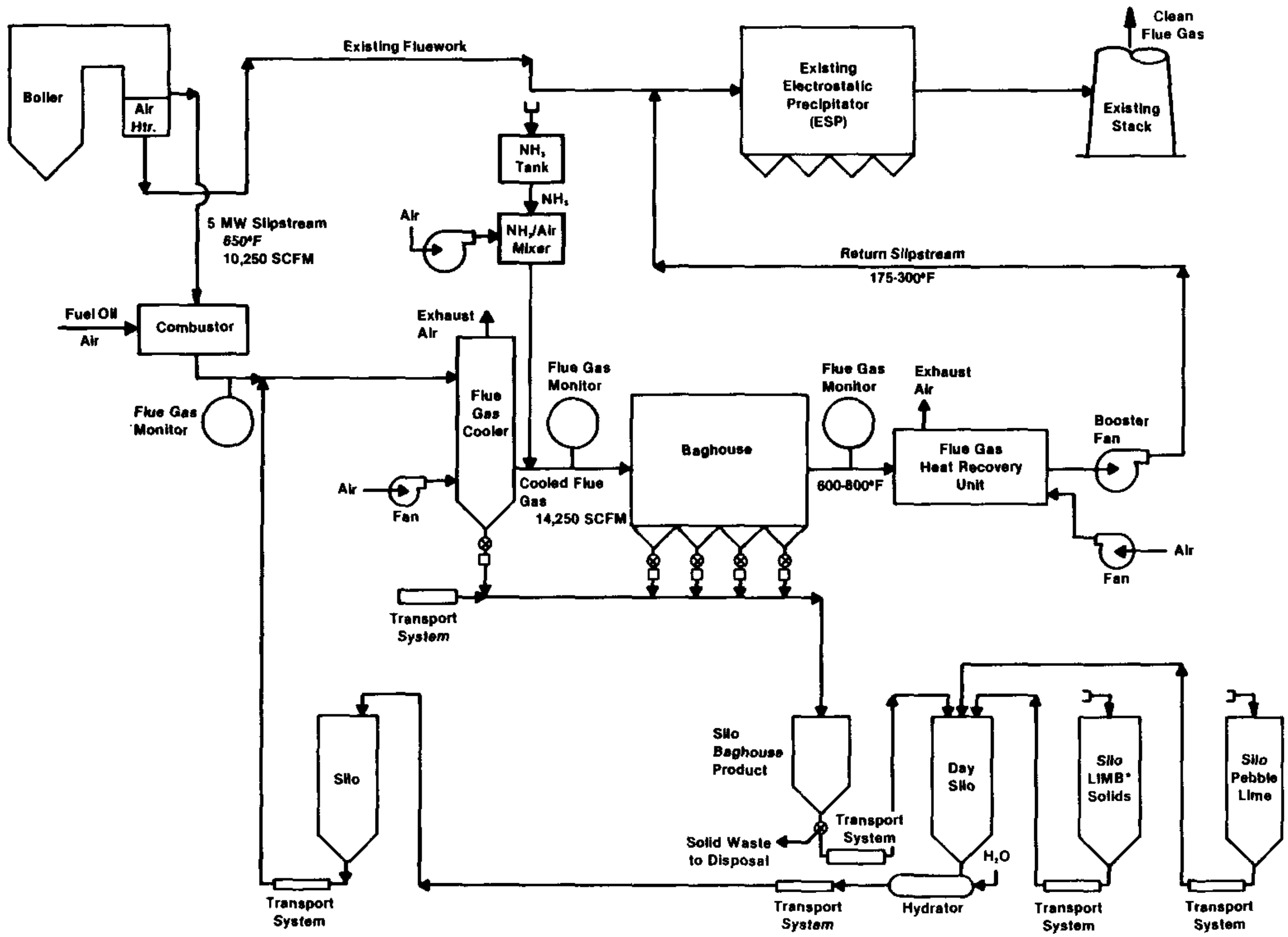
This single process unit, with the upstream injection of sorbent and ammonia, is expected to remove 70% to 90% of the SO_2, 90% of the NO_x, and 99+% of the particulate matter from coal-fired boilers.

In addition, because of the high-temperature operation, the air heater can be located downstream of the baghouse. Since the flue gas entering the air heater will be desulfurized, the flue gas acid dew point will be substantially reduced. This will allow the air heater to operate at a reduced flue gas exit temperature. This lower flue gas exit temperature results in the recovery of additional energy and a significant increase in boiler cycle efficiency.

3.2.3 Application of Processes in Proposed Project

The R.E. Burger Station Boiler No. 8 is a 156-MW pulverized-coal-fired radiant boiler (manufactured by B&W) and is equipped with an electrostatic precipitator. The installation of the SNRB system will require that a branch line (slipstream of flue gas) equivalent to about 5 MWe be taken off upstream of the air heater (also downstream of the economizer). This branch line, containing a high-temperature baghouse and other components, will be used to perform the demonstration. Figure 3 is an overall process flow diagram for the R.E. Burger Boiler No. 8 flue gas system including the SNRB system.

The specific objectives of the SNRB demonstration are to (1) demonstrate 70% to 90% SO_2 removal at a cost-effective sorbent/sulfur ratio, (2) demonstrate up to 90% NO_x removal at a cost-effective ammonia/NO_x ratio, (3) demonstrate 99+% particulate removal, (4) demonstrate these pollutant removal efficiencies in an integrated single unit operation (high temperature baghouse), (5) demonstrate long-term operability of such a unit, (6) demonstrate that the waste product can be safely disposed of in a landfill or used in a manner similar to fly ash wastes from the boiler, and (7) demonstrate the potential for improved boiler efficiency, through lower exit gas temperature, because of a very low SO_3 concentration in the flue gas.



*Waste from Limestone Injection-Multistage Burner

FIGURE 3. GENERAL PROCESS FLOW DIAGRAM FOR SNRB.

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3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As described earlier, much prior work has been performed on the individual portions of the process. Sorbent and ammonia injection equipment has been commercially demonstrated, and high-temperature fabric filter materials and SCR catalysts have been developed and are commercially available. Furthermore, pilot-scale developmental work by B&W has been successful and indicates that a larger scale demonstration is warranted.

There is, however, some risk associated with this demonstration, as described below:

- The conventional means of cleaning filter bags may not be effective, and therefore, other cleaning methods may be required, which could impact bag life, capital costs, and O&M costs.

- Only a limited amount of data exists regarding prior integration testing that verifies that this technology is ready for larger scale demonstration.

- The process removes SO_2 through the injection of calcium-based sorbent at the economizer outlet and upstream of the high temperature baghouse. The removal of SO_2 utilizing a dry sorbent may result in the excessive deposition of solids in downstream equipment and ductwork.

In addition to the technical risk factors described above, a certain amount of economic risk also exists for this project.

- The life of the SCR catalyst has not yet been fully proven for large-scale applications like the SNRB process. In a worst-case scenario, short catalyst life would translate to excessively high O&M costs, which could adversely impact SNRB commercialization.

- Similarly, short bag life, as described above, could adversely impact capital and O&M costs.

However, sufficient testing at bench- and pilot-scale has been done to obtain a reasonable determination of expected catalyst life for this process, and certification of the bag material by high-temperature flue gas tests has also been done.

Based on the above, a moderate risk has been assigned to this project.

3.3.1.1 Similarity of the Project to Other Demonstration and Cǒmmercial Efforts

Except for tests conducted by B&W and UNDEMRC, no known past or current active work is being conducted in regard to the SNRB process. The SNRB process, however, consists of systems and components that are in general use by the utility power industry and other commercial industries. The SNRB process is the unique combination of this conventional equipment. The three principal systems making up the SNRB process are dry sorbent injection, SCR, and high-temperature baghouse filtration.

The removal of SO_2 by sorbent injection is similar to the B&W LIMB process, the Coolside process, and the Dravo Hydrate Addition at Low Temperature (HALT) process. In the B&W LIMB process, the sorbent is injected into the upper part of the furnace combustion zone. In the Coolside and HALT processes, the dry sorbent is injected downstream of the boiler.

The SCR portion of the SNRB process, for NO_x removal, is similar to the Southern Company Services SCR process presently proposed for demonstration under the ICCT program at the Gulf Power Company's Plant Crist Units 5 and 6. In addition, many plants in Europe and Japan have successfully used SCR to reduce NO_x emissions.

The unique features of this demonstration are the high-temperature baghouse and the use of sorbent injection and SCR in conjunction with it.

While each of these systems has individually been commercialized and is widely applied in industry, specific design information under expected SNRB operating conditions can only be obtained from the integrated SNRB demonstration project. Therefore, no portion of the SNRB project can be considered to be unnecessary even though the systems and components have already been successfully demonstrated or are commercially available for other similar processes.

3.3.1.2 Technical Feasibility

The SNRB process has been under development since 1980. The key to the process, the high-temperature baghouse, gave possibility to the concept of combining SO_x, NO_x, and particulate removal in a single unit. This concept was patented by B&W. The results of bench- and pilot-scale research indicate that the SNRB technology is ready for the 5-MW equivalent demonstration. Additional pilot work, jointly funded by B&W and OCDO, will produce more data to improve the expectation that the project will achieve its goals. Also, Norton Company has patented an SCR catalyst that has been tested and commercially used for NO_x reduction applications. Furthermore, the 3M-developed Nextel Ceramic fiber yarn has been successfully tested at high temperatures at UNDEMRC.

The experience of B&W, combined with recent successful test programs funded by OCDO, and the commercial availability of much of the equipment used in the process, indicate that the SNRB technology is feasible and that this demonstration should achieve its goal of 70 to 90% SO_2 and up to 90% NO_x removal.

3.3.1.3 Resource Availability

Adequate resources are available for this project over the forty-four month demonstration period. Babcock & Wilcox will use present members of its staff to fill key and support positions. No new employees will be necessary to perform the work.

Neither the quantity nor the quality of the coal now being burned by the R.E. Burger plant Unit No. 5 will change during the demonstration period. Therefore, this project will not increase the amount of coal required by the host boiler. The project will use ammonia and various sorbents. The availability of these raw materials is expected to be adequate not only for the demonstration period but also for the commercialization of this technology.

This program involves a pre-NSPS boiler installation. The unit is a fully operational steam-boiler and turbine-generator set with appropriate facilities and scheduling flexibility to accommodate this project. The site selected for the proposed demonstration will provide an excellent opportunity to evaluate the technology in essentially all of the situations that are likely to be encountered in the commercialization of the technology. All appropriate resources can be made available to the site such as coal, sorbent, and ammonia. The design, the installation, and the operation and maintenance of the SNRB hardware will be performed by B&W and Ohio Edison personnel. Adequate funds have been committed by the cofunders to cover their share of the estimated project costs.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

As mentioned previously, the test boiler is a 156-MW utility unit, but the demonstration will be conducted using a 5-MW equivalent flue gas slipstream. A larger slipstream would result in significantly higher capital and operating costs without any improvement in the operability or flexibility of the demonstration. The baghouse modules and the bag size will be representative of a commercial-scale utility SNRB system.

Scale-up to larger utility service would involve increasing the sorbent and ammonia injection systems, the number of injection points, and the size and number of baghouse modules. The configuration of the proposed baghouse and SCR system design, however, is uncertain, and therefore, there may be some risk involved in the subsequent scale-up of the demonstration module to commercial size. The risk of scaling-up is considered to be low to moderate because the majority of the process components are currently in commercial operation in large-scale utility and industrial plants. Consequently, this demonstration should prove the technical and economic applicability of the SNRB process for new and retrofit units.

3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology

The SNRB process has the potential to enhance the use of medium- and high-sulfur coals under conditions requiring compliance with environmental regulations. The commercialization of the SNRB technology requires a comprehensive data base that demonstrates the emission control, the performance enhancement, the reliability, and the cost effectiveness of the technology. Commercialization also requires the means to transfer data regarding the technology directly to industry.

3.3.3.1 Applicability of the Data to Be Generated

To collect the necessary accurate performance data, the demonstration will be fully instrumented and will use automated data acquisition equipment. A computerized data acquisition system will interface with B&W home office computer equipment to facilitate data reduction and performance analysis without impacting plant operation. Measurements that will be taken during the demonstration include particulate loading and electric power consumption, as well as sorbent, coal, ash, and water analyses and feed rates. In addition, data on flue gas composition, waste product quantities and composition, flue gas temperatures, unreacted ammonia concentration downstream of the baghouse air heater performance, catalyst pressure drop, and baghouse pressure drop will be obtained. Both transient and steady-state operation will be evaluated.

The test data collected will be reduced and analyzed through the use of a computer program developed for the project. The program will determine overall system performance and have the capability for report formats, data plotting, and data trend determination. Consequently, sufficient data will be collected and analyzed to establish the technical, economic, environmental, health, and safety design criteria for commercialization of the process.

3.3.3.2 Identification of Features That Increase Potential for Commercialization

Once commercially proven, the SNRB process will provide an economical means for simultaneous control of SO_2, NO_x, and particulates. The minimal space requirement and the competitive capital and operating costs of this technology make it attractive for new and retrofit applications.

An SNRB process plant would consist of proven, commercially available equipment and components, such as heat-transfer equipment, feeders, blowers, conveyors, pneumatic transport systems, and fabric filters.

In summary, successful demonstration of this technology will promote commercialization of the SNRB process for the following reasons:

- o The process has the capability to simultaneously remove up to 90% of the SO_2 and NO_x and 99+% of the particulate emissions in a single unit.

- o Capital and operating costs will be less than current, conventional flue-gas cleanup technology.

- o Site space requirements are less than those for conventional flue-gas cleanup technology, allowing easier retrofit engineering.

- The SNRB technology has the potential to increase boiler efficiency.

- The process uses commercially available components.

The success of this demonstration will establish that the SNRB process is a technically and economically viable approach to the control of SO_2, NO_x, and particulates from utility and industrial coal-fired boilers. Accordingly, this technology has the potential to significantly penetrate the pre-NSPS and new boiler markets.

3.3.3.3 Comparative Merits of Project, and Projection of Future Commercial Economics and Market Acceptability

The SNRB process is a viable alternative to wet or dry scrubbing for SO_2 removal plus burner or furnace modifications for NO_x reduction. Conventional scrubbing systems have large site space requirements, reduce plant availability, reduce plant electrical output, produce waste disposal problems (in the case of wet scrubbers), and are high in capital cost. NO_x control technologies have been extensively developed; however, for NO_x reduction systems other than SCR, they are limited in their ability to reduce NO_x to below 300 ppm on U.S.-designed boilers. Consequently, a need exists for a new technology that is efficient, economical, and reliable.

The SNRB process combines SO_2, NO_x and particulate removal in one unit -- a high-temperature baghouse. It requires lower capital and O&M costs compared to conventional systems. It can also increase plant cycle efficiency, and solid waste disposal costs will be less than with wet sorbent systems. Therefore, the utility and industrial sectors should view this technology as an attractive alternate to existing technologies, particularly when applied to pre-NSPS boilers.

An economic comparison was made by B&W between a projected 500-MW eastern SNRB retrofit and an alternative combined wet limestone flue gas desulfurization system and selective catalytic reduction system. The combined capital and levelized operating cost for the SNRB system was estimated to be about 1/3 less than the cost for the wet limestone/SCR systems. In addition, the SNRB retrofit system was estimated to produce a net 22 MW to 30 MW more power than a system retrofitted with a wet scrubber for SO_2 removal and an SCR system for NO_x removal. A similar comparison was made for a projected 500-MW western SNRB retrofit and an alternative combined dry flue gas desulfurization system and selective catalytic reduction system. The combined capital and levelized operating cost for the SNRB system was estimated to be about 1/3 less than the combined dry scrubber and SCR system. Also, the SNRB retrofit system was estimated to produce a net 22 MW to 27 MW more power than the combined dry scrubber and SCR system. These comparisons indicate a clear cost advantage of SNRB technology over conventional flue gas de-SO_x, de-NO_x technologies.

4.0 ENVIRONMENTAL CONSIDERATIONS

The overall strategy for compliance with NEPA, cited in Section 2.2, contains three major elements. The first element, the Programmatic Environmental Impact Analysis (PEIA), was issued as a public document in September 1988. In the PEIA, the Regional Emission Database and Evaluation System (REDES), a model developed by DOE at Argonne National Laboratory, was used to estimate the environmental impacts that could occur by the year 2010 if each technology were to reach full commercialization and captured 100 percent of its applicable market. The environmental impacts were compared to the no-action alternative, which assumes that use of conventional coal technologies continues through 2010, with new plants using conventional flue gas desulfurization controls to meet New Source Performance Standards.

In the PEIA, the expected performance characteristics and applicable market of the SNRB technology were used to estimate the environmental impacts that could result if the SNRB technology were to reach full commercialization in 2010. The REDES computer model was used to project the impacts of the SNRB technology as compared to the no-action alternative.

Projected environmental impacts from maximum commercialization of the SNRB technology into national and regional areas in 2010 are given in Table 1. Negative percentages indicate decreases in emissions or wastes in 2010. Conversely, positive values indicate increases in emissions or wastes. The information presented in Table 1 represents an estimate of the environmental impacts of the technology in 2010. These results should be regarded as approximations of actual impacts.

Table 1. Projected Environmental Impacts in 2010
(Percent Change in Emissions and Solid Wastes)

Region	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NO_x)	Solid Waste
National	-56	-20	+35
Northeast	-76	-50	+36
Southeast	-63	-26	+59
Northwest	-12	- 8	+69
Southwest	-29	-13	+17

Source: Programmatic Environmental Impact Analysis (DOE/PEIA-0002), U.S. Department of Energy, September 1988.

As shown in Table 1, significant reductions of SO_2 and NO_x are projected to be achievable nationally due to the capability of the SNRB process to remove 70-90% of SO_2 and NO_x emissions from coal-fired boilers and the wide potential applicability of the process. Negligible changes in liquid effluents are anticipated because the technology produces a dry solid waste product. Although dry wastes are readily disposable, the amount produced by the SNRB will significantly increase due to sorbent injection. The REDES model predicts that the greatest environmental impacts will be felt in the Northeast because of the large amount of coal-fired capacity that can be retrofitted with the SNRB process. The least impact occurs in the Northwest because of the minimal use of coal. The national quadrants used in this study are shown in Figure 4.

The second element of DOE's NEPA strategy for the ICCT program involved preparation of a preselection environmental review based on project-specific environmental data and analyses that offerors supplied as a part of each proposal. This analysis, for internal DOE use only, contained a discussion of site-specific EHSS issues associated with each demonstration project. It included a discussion of the advantages and disadvantages of the proposed and alternative processes reasonably available to each offeror. A discussion of the impacts of each proposed demonstration on the environment, and a list of permits that must be obtained to implement the proposal, were included. It also contained options for controlling discharges and for management of solid and liquid wastes. Finally, the risks and impacts of each proposed project were assessed. Based on this analysis, no environmental, health, or safety issues have been identified that would result in any significant adverse environmental impacts from construction and operation of the SNRB demonstration facility.

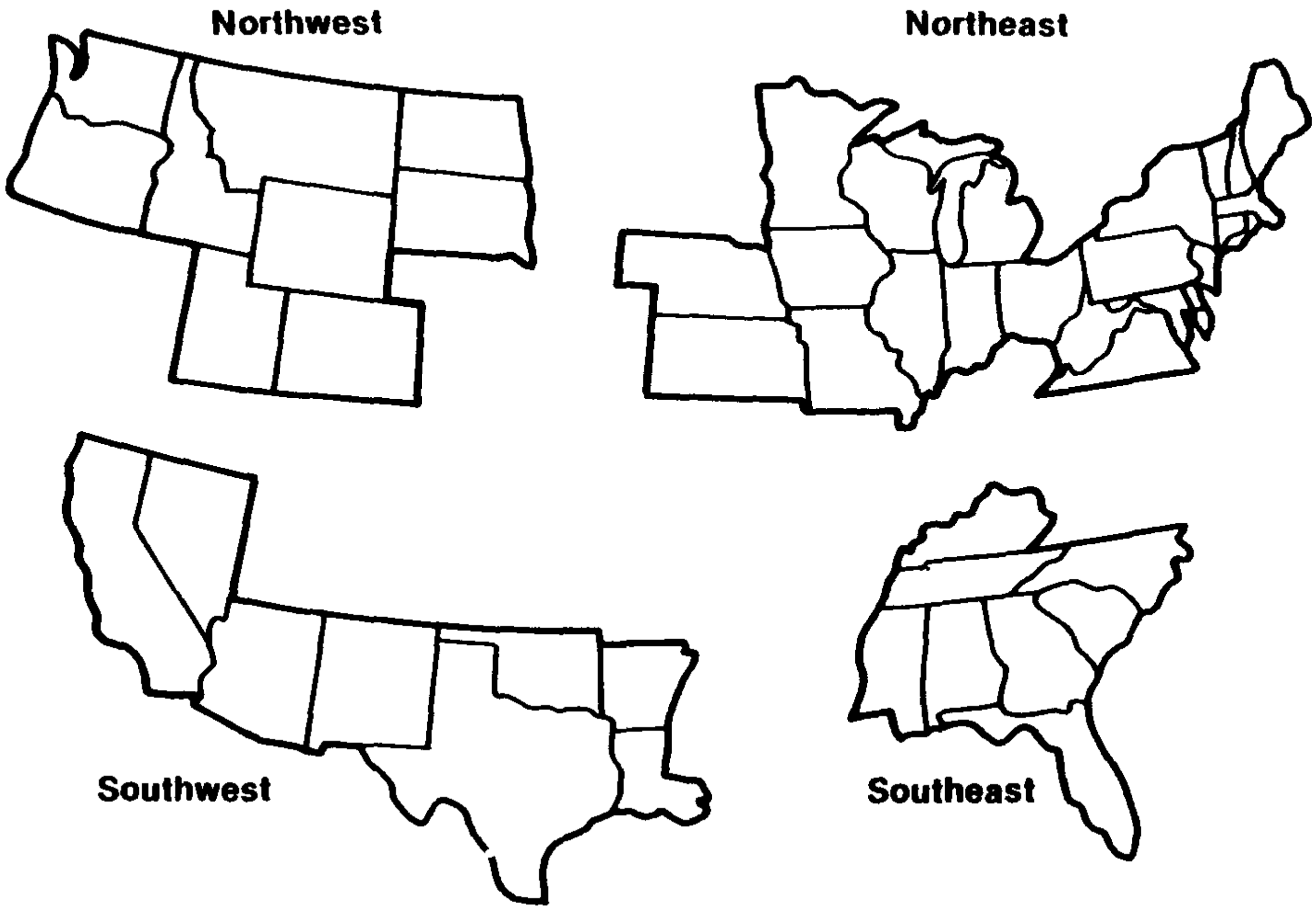

FIGURE 4. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

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As the third element of the NEPA strategy, the Participant (B&W) will be required to submit the environmental information specified in Appendix J of the PON. This detailed site- and project-specific information will be used as the basis for the development of the site-specific NEPA documents to be prepared by DOE. These documents will be completed and approved in full conformance with the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR Parts 1500-1508) and DOE guidelines for NEPA compliance (52 FR 47662, December 15, 1987) before federal funds are provided for detailed design, construction, and operation.

In addition to the NEPA requirements, the Participant must prepare and submit an Environmental Monitoring Plan (EMP). Guidelines for the development of the EMP are provided in Appendix N of the PON. The EMP is intended to ensure that significant technology, project, and site-specific environmental data are collected and disseminated to provide health, safety, and environmental information should the technology be used in commercial applications.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The project will be managed by B&W's Project Manager, who will be the principal contact with DOE for matters regarding the administration of the Cooperative Agreement between B&W and DOE. The DOE Contracting Officer is responsible for all contract matters regarding the administration of this agreement. The DOE Contracting Officer's Technical Representative (COTR) is responsible for technical liaison and monitoring of the project.

A Participant's Advisory Committee will be formed and will be composed of personnel from B&W, DOE, Ohio Edison Company, EPRI, and OCDO. This Committee will meet as needed to review the project, assess plans, and provide advice on correcting any deficiencies.

In addition to DOE and B&W, the project cofunders are the OCDO, EPRI, Ohio Edison Company, Norton Company, and 3M.

5.2 Identification of Respective Roles and Responsibilities

DOE

The DOE will be responsible for monitoring all aspects of the project and for granting or denying all approvals required by the Cooperative Agreement. The DOE Contracting Officer is the authorized representative of the DOE for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a COTR who is the authorized representative for all technical matters and has the authority to issue "Technical Advice" that may

- o Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, and suggest pursuit of certain lines of inquiry, which assist in accomplishing the Statement of Work.

- o Approve those technical reports, plans, and technical information required to be delivered by the Participant to the DOE under the Cooperative Agreement.

The DOE COTR does not have the authority to issue any technical advice that:

- o Constitutes an assignment of additional work outside the Statement of Work.

- o In any manner causes an increase or decrease in the total estimated cost or in the time required for performance of the Cooperative Agreement.

- o Changes any of the terms, conditions, or specifications of the Cooperative Agreement.

- o Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

All technical advice will be issued in writing by the DOE COTR.

Participant

The Participant (B&W) will be responsible for all aspects of project performance under the Cooperative Agreement as set forth in the Statement of Work.

The Participant's Project Manager is the authorized representative for the technical and administrative performance of all work to be performed under the Cooperative Agreement and will be the single authorized point of contact for all matters between the Participant and DOE. The Participant will interrelate between the government and all other project sponsors as shown in Figure 5, Project Organization.

Participant's Committee

The Participant's Advisory Committee will consist of representatives from DOE, Ohio Edison Company, EPRI, and OCDO. This Committee will meet as needed to review the project, assess future plans, recommend shifts in emphasis, and provide advice on correcting any deficiencies. The Participant's Advisory Committee is intended to be a working group of personnel directly involved in the project and will ensure that the objectives of each participating organization will be met. The Participant's Advisory Committee will not direct B&W.

5.3 Summary of Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement is divided into phases and budget periods as follows:

- Phase I: Design and Permitting (Budget Period 1)
- Phase IIA: Long Lead Procurement (Budget Period 1)
- Phase IIB: Procurement, Construction, and Start-up (Budget Period 2)
- Phase III: Operation, Data Collection, Reporting, and Disposition (Budget Period 3)

As shown in Figure 6, the total project encompasses a 44-month period.

Three budget periods will be established to coincide with (1) Phases I and IIA; (2) Phase IIB; and (3) Phase III. The initial budget period will also include certain recognized costs incurred prior to the award of the Cooperative Agreement. Consistent with Public Law No. 100-202, as amended by Public Law

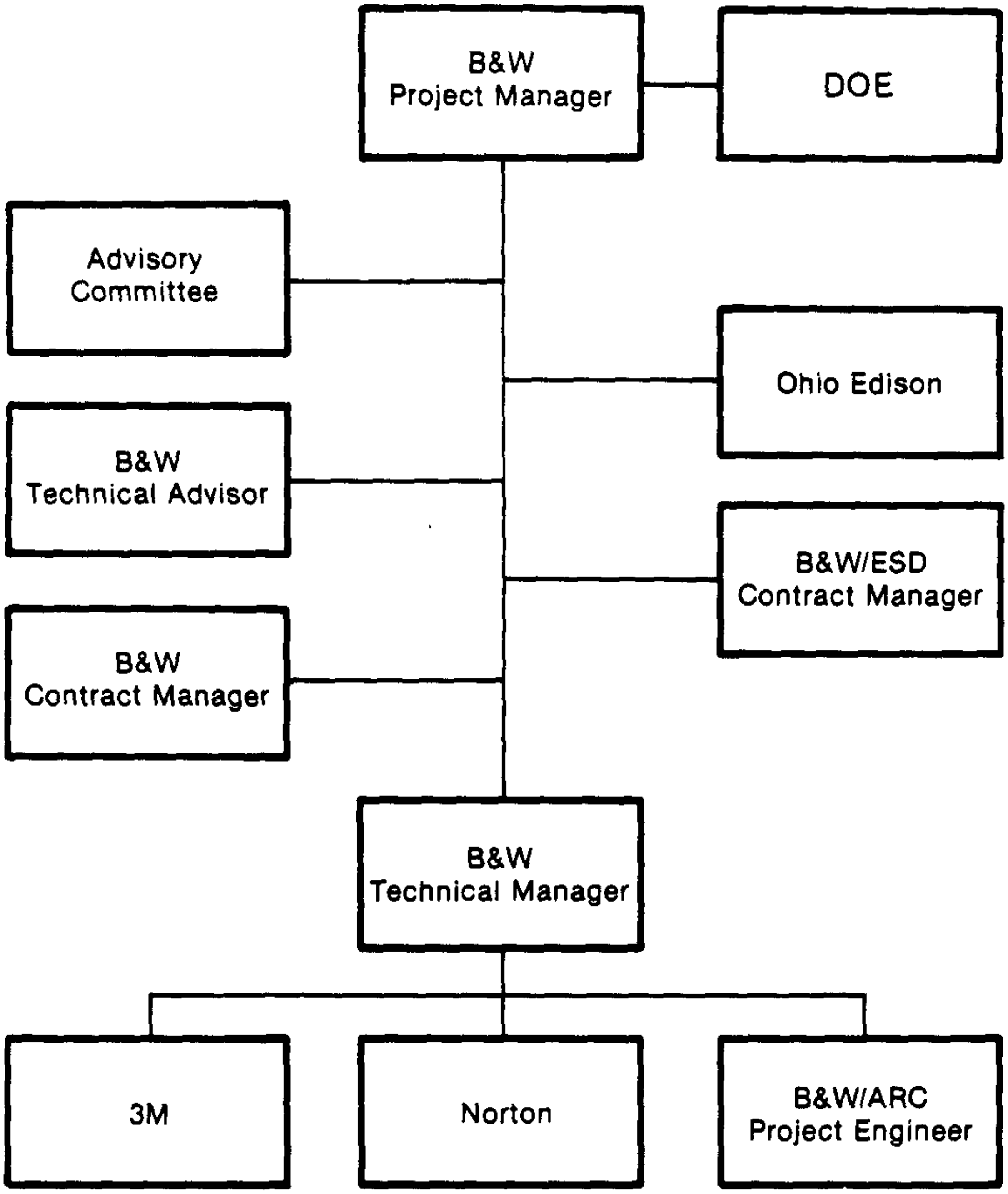

FIGURE 5. B&W PROJECT ORGANIZATION FOR SNRB DEMONSTRATION.

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No. 100-446, DOE intends to obligate sufficient funds to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental-monitoring aspects of the project will be prepared by B&W and provided to DOE.

5.4 Key Agreements Impacting Data Rights, Patent Waivers and Information Reporting

The incentive of B&W to develop this process is to realize retrofit and new installation business from the utility and power boiler industry with respect to SO_2, NO_x, and particulate emissions abatement technology. The key agreements between B&W and DOE with respect to patents and data are as follows:

- o Standard data provisions are included, giving the Government the right to have delivered and use with unlimited rights all technical data first produced in the performance of the Cooperative Agreement.

- o A patent waiver is expected to be granted by DOE giving B&W ownership of foreground inventions, subject to the march-in rights and U.S. preference found in P.L. 96-517.

- o Rights in background patents and background data of B&W and of all of its subcontractors are included to assure commercialization of the technology.

Babcock & Wilcox will make such data, as are applicable and nonproprietary, available to the U.S. DOE, U.S. EPA, Ohio EPA, other interested agencies, and the public.

5.5 Procedures for Commercialization of Technology

If the demonstration is successful, B&W will perform an evaluation of the over 700 candidate units to identify where the SNRB technology can best be applied. Babcock & Wilcox will be the primary marketer of this technology. Marketing efforts will include personal tours of the demonstration site, technical papers presented at appropriate conferences, and sales brochures.

Since the SNRB process was developed by B&W, it will not be necessary for B&W to obtain a license to market it. Babcock & Wilcox will execute business

agreements with 3M
for the use of the

The market for low-
by such government
non-NSPS utility st
emission complianc
anticipated acid ra
units built prior t
over 1,000 units, r

	Dollar Share ($)	Percent Share (%)
Pre-Award		
Government	73,189	45.8
Participant	86,613	54.2
Phase I		
Government	514,458	30.2
Participant	1,190,836	69.8
Phase IIA		
Government	2,052,845	48.6
Participant	2,174,429	51.4
Phase IIB		
Government	1,323,980	48.6
Participant	1,402,395	51.4
Phase III		
Government	910,774	50.0
Participant	910,774	50.0
Total Project		
Government	4,875,246	45.8
Participant	5,765,047	54.2

Contributions will be made by the cofunders as follows:

DOE:	4,875,246
OCDO:	4,374,998
EPRI:	500,000
B&W:	536,559
Norton:	174,290
3M:	101,000
Ohio Edison:	78,200
Total:	10,640,293

At the beginning of each budget period, DOE will obligate sufficient funds to pay its share of the expenses for that budget period.

6.2 Milestone Schedule

The overall project will be completed in 44 months after award of the Cooperative Agreement. The Project Schedule, by phase and activity, is shown in Figure 6.

Phase I (Design and Permitting) was started on July 1, 1989, prior to award, with environmental information gathering and project planning activities, and will continue for nineteen months. Phase IIA (Long-Lead Procurement) will run concurrently with the last eleven months of Phase I. Phase IIB (Procurement, Installation, and Start-Up) will then start and continue for eleven months. Phase III (Operation, Data Collection, Reporting and Disposition) is scheduled to start in the thirtieth month and last for twelve months. The final three months of the program will involve site restoration and completion of the final report for the overall project.

6.3 Repayment Plan

Based on DOE's recoupment policy as stated in Section 6.4 of the PON, DOE is to recover an amount up to the Government's contribution to the project. The Participant has agreed to repay the Government in accordance with the Recoupment/Repayment Plan to be included in the final negotiated Cooperative Agreement.

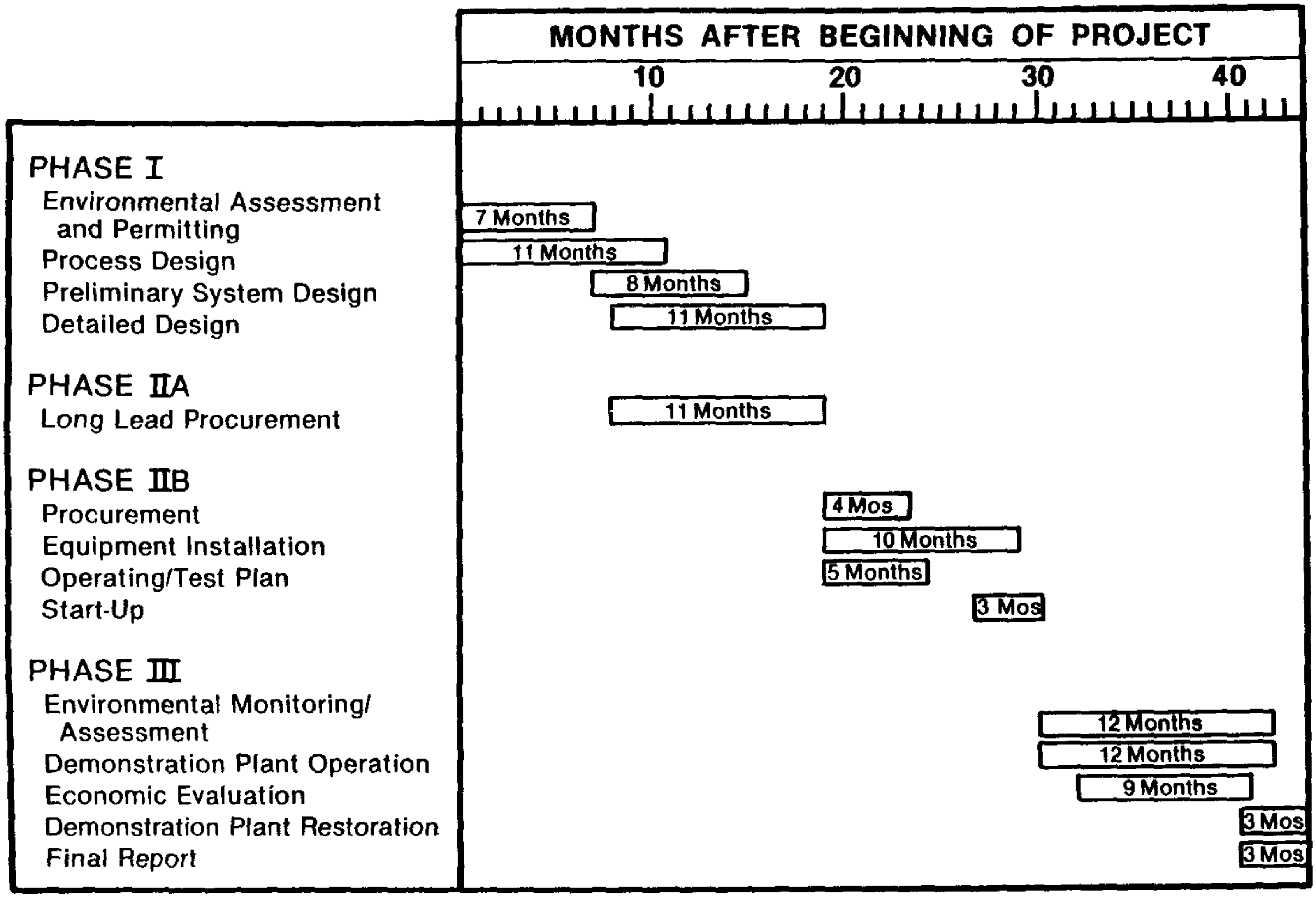

FIGURE 6. OVERALL B&W PROJECT SCHEDULE FOR R.E. BURGER STATION SNRB DEMONSTRATION.

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